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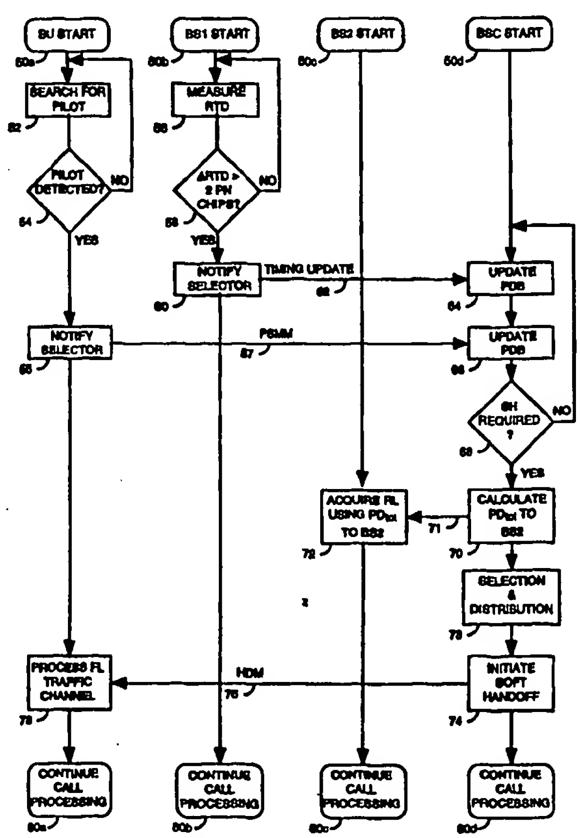
(57) Abstract

A method of and apparatus for tracking propagation delay between a base station and a subscriber unit is described. The method and apparatus may be used in performing an efficient soft handoff in a cellular telephone system. In one embodiment a round trip delay between a base station (32a, 32b) and a subscriber unit (30) is tracked. Changes in the round trip delay at the base station (32a, 32b) are monitored, and updates sent to a base station controller (36) when the delay changes by more than a predetermined amount. Using round trip delay from a first base station and a pilot PN code phase for a pilot received from a second base station, an estimated arrival state of a reverse link signal from the subscriber unit (30) to the second base station is calculated. The estimated arrival state aids acquisition of the reverse link signal by the second base station.



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A METHOD OF AND APPARATUS FOR TRACKING PROPAGATION DELAY BETWEEN A BASE STATION AND A SUBSCRIBER UNIT

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to a method of and apparatus for tracking propagation delay between a base station and a subscriber unit. The present invention may be applied to efficiently performing a soft handoff of a subscriber unit moving from the coverage area of a first base station to the coverage area of a second base station.

II. Description of the Related Art

The IS-95 standard (IS-95) defines a Code Division Multiple Access (CDMA) over-the-air interface for providing efficient and robust cellular telephone service. The IS-95 standard has been approved by the Telecommunication Industry Association (TIA) to allow cellular telephones and base stations manufactured by different suppliers to interoperate with one another. An illustration of a cellular telephone system configured in accordance with the use of the IS-95 standard is provided in FIG. 1. Also, a cellular telephone system configured substantially in accordance with the use of IS-95 is described in US patent 5,103,459 entitled "System and Method for Generating Signal Waveforms in a CDMA Cellular Telephone System" assigned to the assignee of the present invention and incorporated herein by reference.

CDMA signal processing allows a set of user signals to be transmitted over the same radio frequency (RF) band by modulation of the user signals with a set of pseudorandom noise codes (PN codes) before upconvertion to an RF frequency band. The PN codes are used to modulate and demodulate the user signals for transmission and reception processing respectively. Transmitting a set of user signals over the same RF frequency range increases the number of transmission that can be conducted over a given amount of RF bandwidth, by increasing the frequency factor of the cellular telephone system.

To provide increased robustness over prior art cellular telephone systems, IS-95 performs soft handoff as a subscriber unit **10** (typically a cellular telephone) moves from the coverage area of one base station **12** to

the coverage area of another base station **12**. Soft handoff is the process of establishing an RF link with the second base station **12** before terminating the RF link with the first base station. In FIG. 1, one subscriber unit **10** is shown interfacing with two base stations **12** and therefore in soft handoff.

Soft handoff can be contrasted with hard handoff during which the RF link with the first base station **12** is terminated before the RF link with the second base station is established. By maintaining at least one RF link at all times, soft handoff increases the likelihood that the telephone call will continue uninterrupted during the transition from one coverage area to another.

To properly perform CDMA signal processing, the state of PN codes used to process the user signals at the receive system must be the same as the state of the PN codes used at the transmit system. Thus, for processing the forward link transmission from a base station **12** to a subscriber unit **10**, the PN codes at the subscriber unit **10** must be set to the state of the PN codes at the base station **12** plus some additional time equal to the propagation delay experienced during the transmission of the RF signals.

Similarly, for processing the reverse link transmission from a subscriber unit **10** to a base station **12**, the PN codes at the base station **12** must be set to the state of the PN codes at the subscriber unit **10** plus some additional time equal to the propagation delay.

In accordance with the IS-95 standard, each PN code used to generate the pilot channel from each base station **12** is phase offset by multiples of 64 bits, or "chips", with respect to the phase of the pilot PN codes at the other base stations **12**. The phase offset is set to 64•PILOT_PN, where PILOT_PN is a pilot PN offset index that uniquely identifies a base station **12** from other proximately located base stations **12**. The phase offset allows a subscriber unit **10** to identify different base stations **12**. The reverse link signals are modulated with a similar PN code, but without the use of an PN code offset. Rather, subscriber units **10** are identified using an additional code that is unique to each subscriber unit.

To establish a bidirectional RF link between a subscriber unit **10** and a base station **12**, both the forward and reverse link signals must first be acquired. That is, the PN codes used at the receive and transmit systems must be synchronized. When conducting a soft hand-off, any delay in the process of acquiring the reverse link signal is undesirable because, until the acquisition takes place, the IS-95 reverse link power control mechanism cannot be attempted. Without reverse link power control, the reverse link signal from the subscriber unit **10** is generated at excessively high levels, and

therefore unduly interferes with the transmission of other subscriber units **10** operating in the coverage area of the second base station **12**. Thus, to improve the performance of a cellular telephone system, the present invention is directed to reducing the time necessary to perform reverse link signal acquisition during a soft hand-off.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a novel and improved method and apparatus for efficiently performing a soft handoff in a cellular telephone system.

In one aspect the invention provides a method for tracking a first propagation delay between a first base station and a subscriber unit comprising: tracking changes in the first delay to said first base station; and notifying a base station controller when said first delay changes by a predetermined amount.

In another aspect the invention provides a system for providing wireless communications, the system comprising: subscriber unit for generating pilot strength measurement report indicating a phase offset of received pilot channel; first base station for generating a timing update message when a first propagation delay between said first base station and said subscriber unit changes more than a predetermined amount; base station controller for generating an estimated delay using said phase offset and said first delay; and second base station for performing a signal acquisition initiated at said estimated delay.

In a further aspect the invention provides a wireless telecommunications system for tracking a first delay to a subscriber unit comprising: a base station for generating a timing update message when said first delay changes by a predetermined amount; and a base station controller for updating a pilot database using said timing update message.

The invention also provides a wireless telecommunications system for tracking a first delay to a subscriber unit comprising: transmission means for generating a timing update message when said first delay changes by a predetermined amount; and controller means for updating a pilot database using said timing update message.

The invention further provides a controller for controlling communication with a subscriber unit by measuring the time taken for a signal to travel from one communication system and back via the subscriber

unit and selecting either the one or another communication system for communication with the subscriber unit depending on the time taken.

In one embodiment of the invention, a propagation delay between a base station and a subscriber unit is tracked. The tracking is performed by monitoring changes in the round trip delay at the base station, and notifying a base station controller when a change exceeding a predetermined amount occurs. Using the round trip delay, and a pilot PN code phase of a pilot channel from a second base station, an estimated arrival state of a reverse link signal from the subscriber unit to the second base station is calculated. This estimated arrival state facilitates acquisition of the reverse link signal by the second base station.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below of an embodiment of the invention when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is an illustration of a cellular telephone system configured in accordance with the use of the IS-95 standard;

FIG. 2 is a block diagram of a portion of cellular telephone system configured in accordance with an exemplary embodiment of the invention;

FIG. 3 is a flow chart of the operation of the various systems that make up the cellular telephone system in accordance with one embodiment of the invention; and

FIG. 4 is a timing diagram illustrating the calculation of the arrival state when performed in accordance with one embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A novel and improved method and apparatus for performing an efficient soft handoff is described. In the following description, the embodiment of the invention is set forth in the context of a CDMA cellular telephone system operating in accordance with the IS-95 standard. While the invention is especially suited for operation with a cellular telephone

system operating in accordance with the IS-95 standard, other wireless communication systems including satellite based systems may incorporate the use of the present invention, as may wireline systems that incorporate the use of sinusoidal signals such as coaxial cable communications systems.

FIG. 2 is a block diagram of a portion of cellular telephone system configured in accordance with an exemplary embodiment of the invention. In the location shown, subscriber unit **30** has established a bidirectional RF link with base station **32a**. Base stations **32a** and **32b** are coupled to CDMA interconnect subsystem (CIS) **40** via wire line connections.

CIS **40** is located within base station controller (BSC) **36** and is coupled to selector subsystem **38**, and management system **44**. The various systems that make up BSC **36** as well as base stations **32** exchange data and control information via the use of network packets which contain an address that allows routing by CIS **40**. During operation, management system **44** configures and controls selector subsystem **38** and base stations **32** using subscriber information contained in subscriber data base **46**.

In accordance with the IS-95 standard, each base station **32** transmits a forward link RF signal comprised of a set of subsignals referred to as channels. The channels include a pilot channel which facilitates acquisition and processing of the forward link signal, as well as a set of traffic channels, each of which is used to conduct the forward link portion of a telephone call with a subscriber unit **30**.

As shown, base station **32a** is interfacing with subscriber unit **30**, and therefore one traffic channel from base station **32a** is being used to transmit to subscriber unit **30**. Additionally, subscriber unit **30** is transmitting a reverse link signal that is being received and processed by base station **32a**. Data transmitted via the forward and reverse link signals is processed in frames of 20 ms duration.

Frames received by base station **32a** are routed in network packets to selector subsystem **38** via CIS **34**. Selector subsystem **38** allocates a selector resource (selector) for each call being processed by a corresponding subscriber unit **30**. In the preferred embodiment of the invention, the selector is a set of software instructions executed on one or more microprocessors (not shown).

The selector resource performs various functions that allow mobile communications to take place. One function is keeping track of the set of pilot channels that have recently been detected by the subscriber unit **30** determine when a soft handoff is required. The pilot channel information is stored in a pilot database (PDB) that is updated by the selector in response

to pilot strength measurement message (PSMM) received from subscriber unit 30. Subscriber unit 30 generates a PSMM when it detects a pilot channel from other base stations 32 with sufficient strength and duration during periodic searches for pilot channel performed during the course of conducting a telephone call or other communication.

For each base station 32 interfacing with a subscriber unit 30 the selector also tracks the round trip delay of a transmission from base station 32 to subscriber unit 30 and back. The round trip delay (RTD) is measured by each base station 32 and reported back to the selector. The base station 32 measures the RTD by monitoring the difference in the state of the PN codes used to demodulate the earliest usable reverse link signal from the subscriber unit 30 and the state of a zero offset PILOT_PN sequence. The state of the PN code used for demodulation is constantly adjusted at the base station 32 to track changes in the arrival time of the reverse link signal as the subscriber unit 30 moves. Thus, the round trip delay to subscriber unit 30 is continuously tracked by the base station 32.

In one embodiment of the invention, each base station 32 reports the round trip delay to the selector when a change more than two PN code bits, or "chips," occurs. The round trip delay is reported to the selector using a timing update signaling message transmitted from the base station 32. The selector responds by updating the PDB to indicate the new round trip delay.

By reporting the round trip delay only when a change of more than 2 PN chips occurs, the number of signaling messages that must exchanged between the base station 32 and the selector within BSC 36 in order to maintain an accurate round trip delay in the PDB is reduced. Reducing the number of signaling messages decreases the network resources, required for orderly operation of the cellular telephone system. Additionally, the accuracy of the round trip delay that is stored in the PDB is maintained within 2 PN chips.

While a threshold of 2 PN chips for reporting the round trip delay is preferred, the use of other durations may be employed in alternative embodiments of the invention. In the case where alternative thresholds are used, a duration that is greater than 2 PN chips is preferred, because using a duration of less than 2 PN chips unnecessarily increases the number of signaling messages transmitted between the base station 32 and the selector, thus reducing the overall signaling capacity of the cellular network.

This round trip delay reporting method can be contrasted with, for example, the periodic transmission of signaling messages indicating the round trip delay between the subscriber unit 30 and the base station 32.

Periodically transmitting round trip delay update messages would increase the number of signaling messages transmitted for each telephone call, and when a significant number of telephone calls are being conducted the number of timing update messages generated would interfere with the capacity of the cellular system to process user data, which is the primary purpose of the cellular telephone system.

In an alternative embodiment of the invention, the base station **32** reports the round trip delay using changes in the round trip delay, or "delta" values, rather than the absolute value of the round trip delay. For example, when the round trip delay increases by 3.5 ms, the base station **32** transmits a signaling message that includes the 3.5 ms value. When the round trip delay decreases by 3.5 ms, the base station **32** transmits a signaling message that includes a negative 3.5 ms value. Typically, reporting a delta value requires fewer information bits than reporting an absolute value, which further reduces the amount of data necessary to maintain an accurate measure of the round trip delay.

The selector performs call selection and call distribution in addition to the processing described above. Call selection involves selecting a single network packet from a set of network packets received from the set of base stations with which a subscriber unit **30** is interfacing during soft handoff. The selected packet is then used for further processing. Call distribution is the duplication and distribution of network packets to the set of base stations **32** in communication with a subscriber unit **30** during soft handoff so that each base station **32** may transmit the data frame contained in the network packet to the subscriber unit **30** via the forward link signal.

FIG. 3 is a flow chart illustrating the steps performed by subscriber unit **30**, first and second base stations **32a** and **32b**, and a selector within selector subsystem **38** during an exemplary telephone call performed in accordance with one embodiment of the invention. The processing begins at steps **50a** - **d** during an ongoing call in which a subscriber unit **30** is interfacing with base station **32a**.

At step **52**, subscriber unit **30** searches for pilot channels from other base stations **32** while continuing to processes the telephone call. If, at step **54**, subscriber unit **30** determines that a pilot channel from another base station was not detected with sufficient strength and duration, step **52** is performed again.

If, at step **54**, subscriber unit **30** determines that a pilot channel from another base station **32**, such as the second base station **32b**, was detected with sufficient strength and duration, subscriber unit **30** notifies the selector

within BSC 36 via pilot strength measurement message (PSMM) 57, transmitted at step 55. Typically, detection of the pilot channel from another base station such as the second base station **32b** corresponds to entry into the coverage area of the second base station **32b**.

In the preferred embodiment of the invention, the method by which subscriber unit 30 determines when to transmit the PSMM is described in US Patent No. 5,267,261 entitled "Mobile Station Assisted Soft Handoff in a CDMA Cellular Communications System" incorporated herein by reference ('261), and Chapter Six of the IS-95 standard.

Additionally, in the preferred embodiment of the invention, the PSMM indicates the pilot PN code phase ($PILOT\_PN\_PHASE_2$) of the pilot channel received from the second base station when detected by the subscriber unit 30. In the preferred embodiment, the pilot PN code phase is calculated as follows:

$$PILOT\_PN\_PHASE_2 = [PILOT\_ARRIVAL_2 + (64 \times PILOT\_PN_2)] \bmod 2^{15}. \qquad (1)$$

$PILOT\_PN_2$ is the PN offset index of the second base station **32b** which, as noted above, is in units of 64 pilot PN chips. The mod 2^{15} term accounts for the period of the pilot PN code in PN chips, and $PILOT\_ARRIVAL_2$ is the arrival time at the subscriber unit 30 of the earliest usable multipath component of the pilot channel from the second base station **32b** relative to the time reference in PN chips. In the preferred embodiment of the invention, the time reference is established by the earliest arriving pilot channel from any base station 32, including any multipath component of that pilot channel. In general, the earliest arriving pilot channel is from the closest base station 32, which in the example shown is the first base station **32a**. Thus, $PILOT\_PN\_PHASE_2$ is simply the difference between the arrival time of the pilot channel from the first base station **32a** and the arrival time of pilot channel from the second base station **32b** in PN chips, plus the pilot channel offset of the second base station in PN code chips, which is $64*PILOT\_PN_2$.

Upon receipt of PSMM 57, the selector updates the pilot database with the value $PILOT\_PN\_PHASE_2$. The pilot database (PDB) keeps track of a set pilot channels that have been detected by subscriber unit 30 including the associated pilot PN code phase PILOT_PN_PHASE of those pilot channels. The PDB also calculates the one way propagation delay (propagation delay) between subscriber unit 30 and each base station 32 in the active set as half the round trip delay. That is, the PDB calculates the propagation delay for

each base station 32 that the subscriber unit 30 is currently interfacing with. In the present case, the PDB would only calculate the propagation delay to the first base station 32a since it is the only base station with an interface has been established. As described in greater detail below, the selector then uses $PILOT\_PN\_PHASE_2$ and the propagation delay to the first base station 32a to calculate the propagation delay to the second base station 32b to aid in the acquisition of the reverse link signal at the second base station 32b.

Still referring to FIG. 3, to maintain the accuracy of the round trip delay stored in the PDB, the first base station 32a measures the round trip delay of transmissions exchanged with from subscriber unit 30 (RTD) at step 56. The round trip delay may be measured at the first base station 32a in various ways, including comparing the state of the PN codes used to demodulate the reverse link signal with the state of a zero offset PN code, or by comparing the time at which frame edges occur at transmission and reception.

If it is determined at step 58 that the change in the round trip delay is less than the duration of 2 PN chips, step 56 is performed again. Since the spreading rate as specified by IS-95 is 1.2288 Megachips per second (Mcps), the threshold used in the preferred embodiment of the invention is 1.6276 microseconds (μs).

If it is determined at step 58 that the change in the round trip delay is equal to or greater than 2 PN chips, the first base station 32a notifies the selector of the new propagation delay at step 60 via timing update message 62. While the use of 2 PN chips as the threshold for notifying the selector is preferred, other thresholds are consistent with the use of the present invention.

At step 64, BSC 36 receives timing update message 62 and updates the pilot database (PDB) at step 64. As noted above, the PDB keeps track of the round trip delay to each base station 32 with which communication has been established. To perform the update, the round trip delay within the PDB is updated to that indicated in timing update message 62.

At step 66, BSC 36 receives PSMM 57 indicating that the pilot channel from the second base station 32b has been detected with a particular strength and duration and the pilot PN code phase $PILOT\_PN\_PHASE_2$ of the pilot channel. BSC 36 responds by recording detection of the pilot channel from the second base station 32b in the PDB along with the pilot PN code phase $PILOT\_PN\_PHASE_2$.

At step 68, BSC 26 determines whether a soft handoff (SH) is necessary. In the preferred embodiment of the invention this

determination is performed in accordance with the above referenced '261 patent, and as described in the IS-95 standard. In general, however, the determination is based on whether the pilot channel from base station **32b** has been detected with a second predetermined strength and duration. If it is determined at step **68** that a soft handoff is not necessary, BSC **26** performs step **64** again.

If it is determined at step **68** that a soft handoff is necessary, BSC **26** calculates the estimated arrival state at the second base station **32b** of the reverse link signal PN code based on the round trip delay and the pilot PN code phase $PILOT\_PN\_PHASE_2$ as described below. Base station **32b** then begins acquisition of the reverse signal at step **72** using the reverse link PN code initialized at the estimated arrival state. By initializing the PN codes at the estimated arrival state, the time required for the acquisition process is, on average, reduced, as the state of PN codes is more likely to be close to the actual state of the received reverse link signal reducing the necessary searching.

FIG. **4** is a timing diagram illustrating calculation of the estimated arrival state of the reverse link signal PN code within BSC **26** when performed in accordance with one embodiment of the invention. Time is represented on the horizontal axis, and the position of the first base station **32a** (labeled BS1), the second base station **32b** (labeled BS2), and subscriber unit **30** (labeled SU) is shown on the vertical axis. The graphed lines represent exemplary transmissions between these various systems.

The estimated arrival state is calculated by first determining the difference in the propagation delays between the second base station **32b** and subscriber unit **30**, and the first base station **32a** and subscriber unit **30** as $pd_{b2} - pd_{b1}$ (Δpd), where pd_{b2} is the propagation delay to the second base station **32b** and pd_{b1} is the propagation delay to the first base station **32a**. As noted above the PDB calculates the propagation delay as one-half the round trip delay.

In one embodiment of the invention, Δpd is calculated by the selector as the pilot code phase $PILOT\_PN\_PHASE_2$ minus the PILOT_PN offset of the reference pilot channel (from the first base station **32a** in the example) in PN chips as follows:

$$\Delta pd = [PILOT\_PN\_PHASE_2 - (64 \times PILOT\_PN_2)] \bmod 2^{15} \qquad (2)$$

Equation (2) simply removes the PN offset for second base station **32b** in PN chips (i.e. $64 \times PILOT\_PN_2$) from the pilot phase of the second base

station **32b** (PILOT_PN_PHASE$_2$) yielding the difference between the arrival time of the reference pilot channel from the first base station **32a** and the pilot channel from the second base station **32b** in PN chips. The difference in the arrival time of the two pilot channel corresponds to the difference in the propagation delay from subscriber unit **30** to the first base station **32a** and the propagation delay from subscriber unit **30** to the second base station **32b**, i.e. Δpd. Those skilled in the art will recognize other ways to calculate Δpd using the information stored in the PDB.

Using the difference in the propagation delays Δpd, the actual propagation delay from the second base station **32b** to subscriber unit **30** pd_{b2} can be determined as $pd_{b1} + \Delta pd$, or $pd_{b1} + (pd_{b2} - pd_{b1})$. As shown in FIG. 4, the propagation delay pd_{b2} is the sum of the propagation delay from the first base station **32a** to the subscriber unit **30** pd_{b1} and difference in the propagation delays Δpd.

Once pd_{b2} is calculated, the total propagation delay (pd_{tot}) from the first base station **32a** to subscriber unit **30**, and then from subscriber unit **30** to the second base station **32b** is calculated as $pd_{b2} + pd_{b1}$. The arrival state of the reverse link PN code at the second base station **32b** is then estimated based on system time at the first base station **32b** plus the total propagation delay (pd_{tot}). This calculation provides a reasonable estimate of the arrival state of the reverse link PN code at the second base station **32b** because the internal timing of subscriber unit **30** is set one propagation delay pd_{b1} later than system time at the first base station **32a**, and the reverse link signal generated by subscriber unit **30** is received at the second base station **32b** one propagation delay pd_{b2} after that. Hence, the total propagation delay pd_{tot} is equal to $pd_{b2} + pd_{b1}$.

Referring again to FIG. 3, the total propagation delay pd_{tot} is transmitted to the second base station **32b** in signaling message **71** (FIG. 3). The second base station **32b** then estimates the arrival state of the reverse link signal as the pilot PN code state minus propagation delay pd_{tot} as follows:

$$\text{ARRIVAL\_STATE} = [\text{PILOT\_PN\_STATE}_{zero\_offset} + pd_{tot}]. \quad (3)$$

$\text{PILOT\_PN\_STATE}_{zero\_offset}$ is the PN code state of the zero offset pilot sequence and pd_{tot} is the sum of the propagation delay from the first base station **32a** to the subscriber unit **30** and the propagation delay from the second base station **32b** to the subscriber unit **30**. In the preferred embodiment of the invention, the zero offset pilot PN code state is

determined based on the system time known to each base station **32**. In alternative embodiments of the invention, the estimated arrival state of the pilot PN code for the reverse link signal could be calculated by the selector rather than by the second base station **32b**.

It will be apparent that the arrival state of the reverse link signal will most likely correspond to the zero offset PN code state **32a** plus propagation delay pd_{tot} because the internal timing of subscriber unit **30** is set one propagation delay pd_{b1} later than system time at the first base station **32a**, and the reverse link signal generated by subscriber unit **30** using that internal timing is received at the second base station **32b** one propagation delay pd_{b2} after that. Thus, by tracking the propagation delay to the first base station **32a** pd_{b1} and the pilot PN code phase $PILOT\_PN\_PHASE_2$ of the second base station **32b**, the propagation delay to the second base station **32b** pd_{b2} and the total propagation delay pd_{tot} can be calculated, and the arrival state of the reverse link PN codes at the second base station estimated.

As noted above, the PN codes used for the reverse link signal are generated with an offset of zero, rather than offset by some non-zero PN offset value as performed for the forward link. However, any such non-zero PN offset in the reverse link PN code can be accounted for in equation (3) by substituting the offset pilot PN sequence for the zero offset pilot PN sequence.

At step **73** the selector begins to perform the selection and distribution function by forwarding traffic data to the second base station **32b** at well as the first base station **32a**, and selecting from data received from the second base station **32b**.

At step **74**, the selector within BSC **26** initiates the soft handoff by transmitting handoff/extended-handoff direction message (HDM) **76** to subscriber unit **30** via the forward link traffic channel from the first base station **32a**. At step **78**, the subscriber unit receives HDM **76** and begins to process the traffic channel from the second base station **32b**, and the soft handoff has been established. Each system continues to process the call in soft handoff at steps **80a - d**.

By tracking the round trip delay to the first base station **32a** (RTD), and updating that round trip delay only when a change that is greater than a predetermined amount occurs, the described invention allows the round trip delay to be tracked accurately at a base station controller **36** while minimizing the number of signaling message exchanged between the base station **32** and the base station controller **36**. Maintaining an accurate measurement of the round trip delay using a minimum number of

signaling messages, in turn, allows an estimated arrival state of the reverse link signal at the second base station **32b** to be accurately calculated, without reducing the communication capacity between the base station **32** and the subscriber unit **30** to be used for transmitting user data. This increases the number of calls that be conducted, or decreases the necessary signaling capacity between the base station and the base station controller.

Thus, a novel and improved method and apparatus for efficiently performing a soft handoff is described. The previous description of the preferred embodiment is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. In particular, while the invention is described in the context of a particular configuration of a base station controller, the present invention may be also be implemented using alternatively configured base station controllers. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. A method for tracking a first propagation delay between a first base station and a subscriber unit comprising:

tracking changes in the first delay to said first base station; and

notifying a base station controller when said first delay changes by a predetermined amount.

2. The method as set forth in claim 1 wherein said predetermined amount is equal to approximately 1.6276 μs.

3. The method as set forth in claim 1 or 2 wherein said base station controller is coupled to a second base station.

4. The method as set forth in claim 3 further comprising:

calculating a second delay as a pilot channel phase offset of said second base station less a pilot offset of said second base station; and

initiating an acquisition sequence at said second base station using said first propagation delay and said second delay.

5. The method as set forth in any preceding claim wherein the tracking comprises comparing the state of a modulation PN code and a demodulation PN code.

6. A system for providing wireless communications, the system comprising:

subscriber unit for generating pilot strength measurement report indicating a phase offset of received pilot channel;

first base station for generating a timing update message when a first propagation delay between said first base station and said subscriber unit changes more than a predetermined amount;

base station controller for generating an estimated delay using said phase offset and said first delay; and

second base station for performing a signal acquisition initiated at said estimated delay.

7. The system as set forth in claim 6 wherein said predetermined amount in approximately 1.6276 ms.

8. A wireless telecommunications system for tracking a first delay to a subscriber unit comprising:

a base station for generating a timing update message when said first delay changes by a predetermined amount; and

a base station controller for updating a pilot database using said timing update message.

9. The wireless communication system of claim 8 wherein said base station controller is further for generating an estimated delay between a second base station and the subscriber unit.

10. The wireless communication system of claim 9 wherein said second base station performs a signal acquisition initiated at said estimated delay.

11. The wireless communication system of claim 9 or 10 wherein said estimated delay is a timing difference received from the subscriber unit minus said first delay.

12. A wireless telecommunications system for tracking a first delay to a subscriber unit comprising:

transmission means for generating a timing update message when said first delay changes by a predetermined amount; and

controller means for updating a pilot database using said timing update message.

13. The wireless communication system of claim 12 wherein said controller means is further for generating an estimated delay between a second transmission means and the subscriber unit.

14. The wireless communication system of claim 13 wherein said second transmission means performs a signal acquisition initiated at said estimated delay.

15. The wireless communication system of claim 13 or 14 wherein said estimated delay is a timing difference received from the subscriber unit minus said first delay.

16. A controller for controlling communication with a subscriber unit by measuring the time taken for a signal to travel from one communication system and back via the subscriber unit and selecting either the one or another communication system for communication with the subscriber unit depending on the time taken.

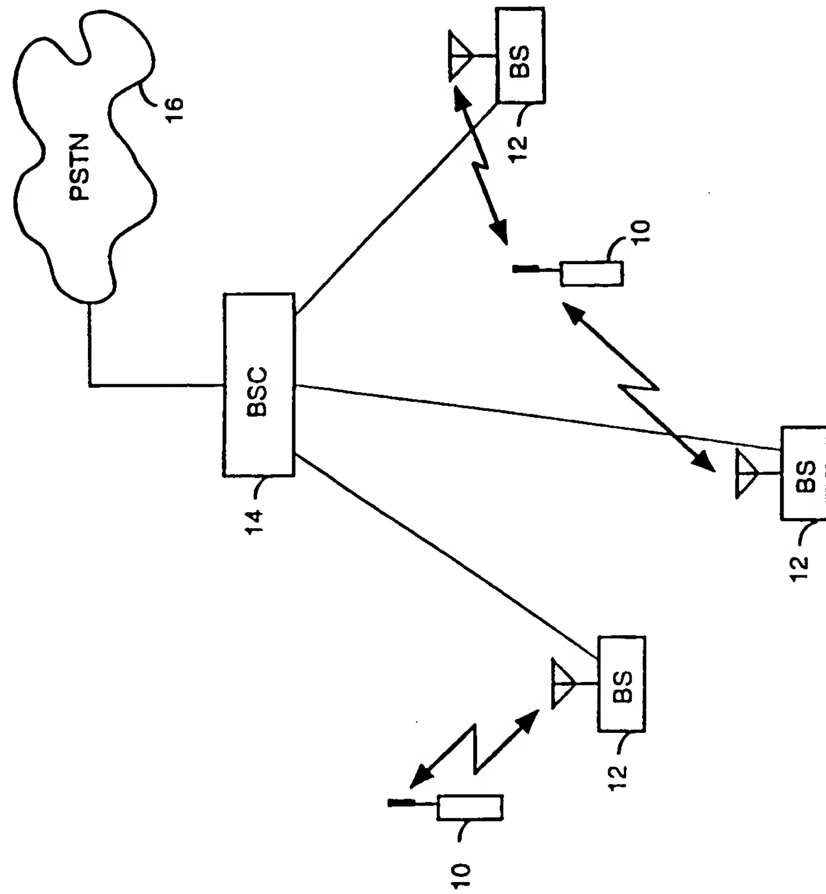

FIG. 1

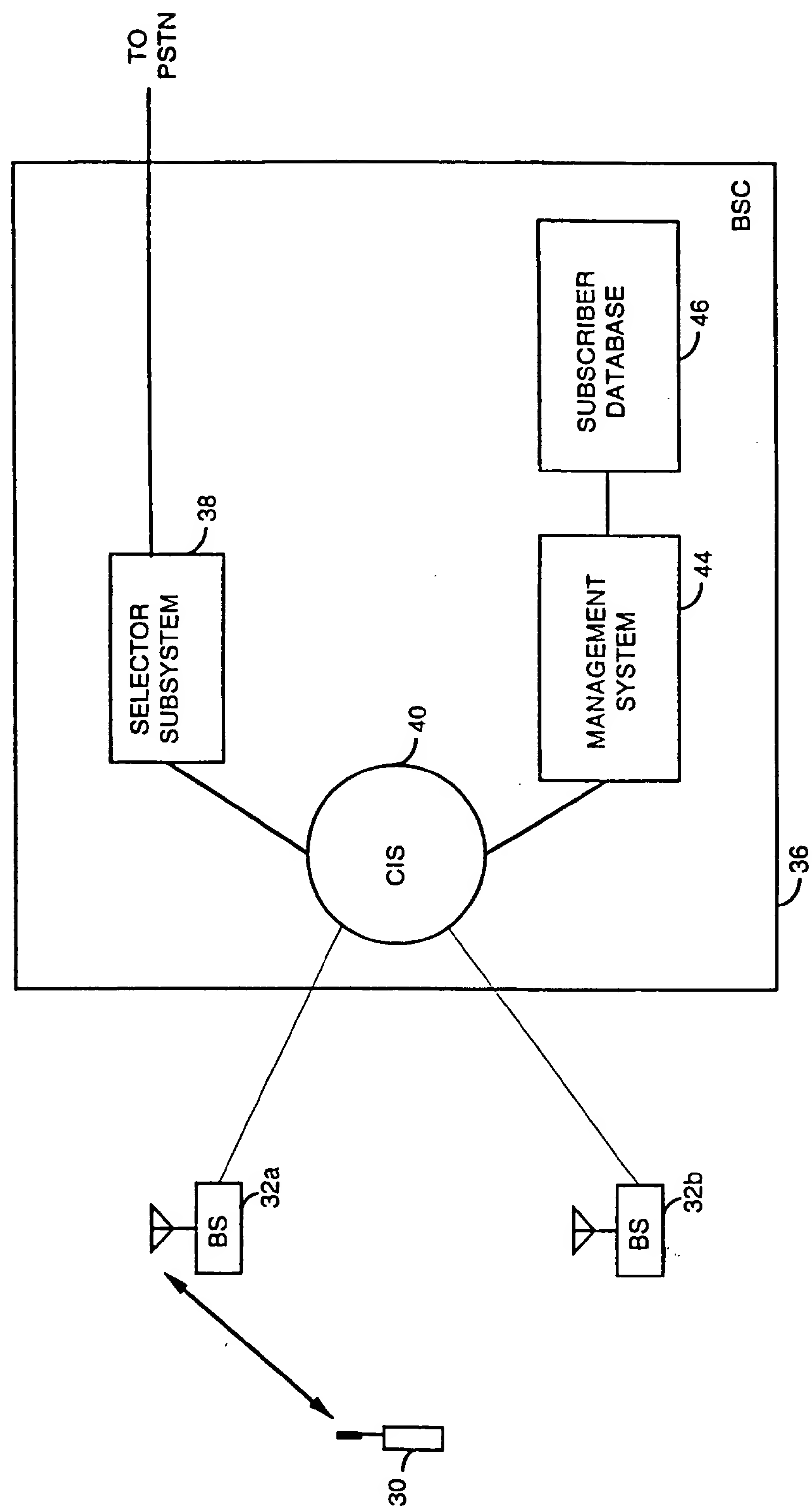
TO PSTN
BSC
SUBSCRIBER DATABASE
46
38
SELECTOR SUBSYSTEM
44
MANAGEMENT SYSTEM
40
CIS
36
BS
32a
BS
32b
30

FIG. 2

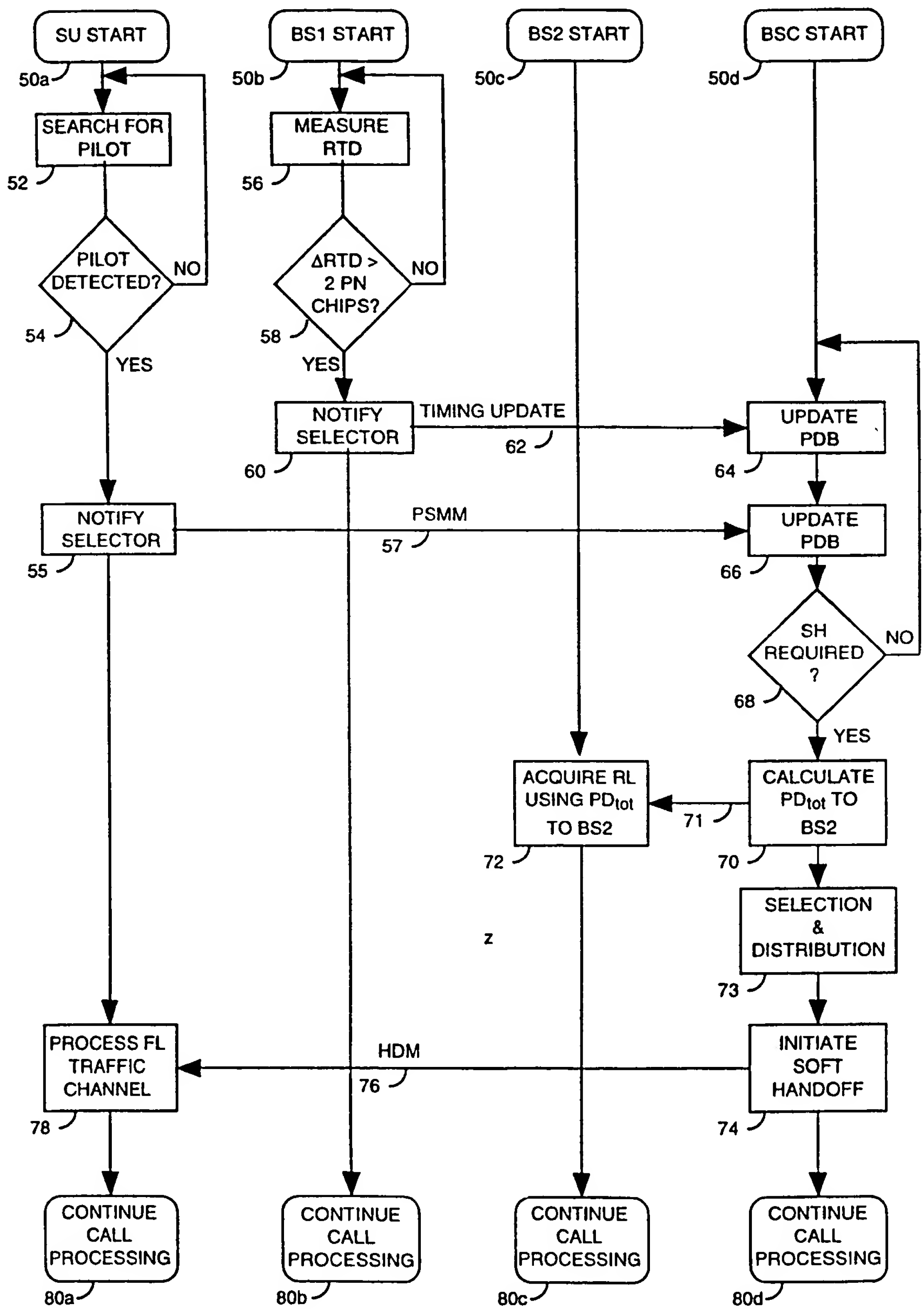
SU START
50a
SEARCH FOR PILOT
52
PILOT DETECTED?
NO
54
YES
NOTIFY SELECTOR
55
PROCESS FL TRAFFIC CHANNEL
78
CONTINUE CALL PROCESSING
80a
BS1 START
50b
MEASURE RTD
56
ΔRTD > 2 PN CHIPS?
NO
58
YES
NOTIFY SELECTOR
60
TIMING UPDATE
62
PSMM
57
HDM
76
CONTINUE CALL PROCESSING
80b
BS2 START
50c
ACQUIRE RL USING PDtot TO BS2
72
z
CONTINUE CALL PROCESSING
80c
BSC START
50d
UPDATE PDB
64
UPDATE PDB
66
SH REQUIRED ?
NO
68
YES
CALCULATE PDtot TO BS2
71
70
SELECTION & DISTRIBUTION
73
INITIATE SOFT HANDOFF
74
CONTINUE CALL PROCESSING
80d

FIG. 3

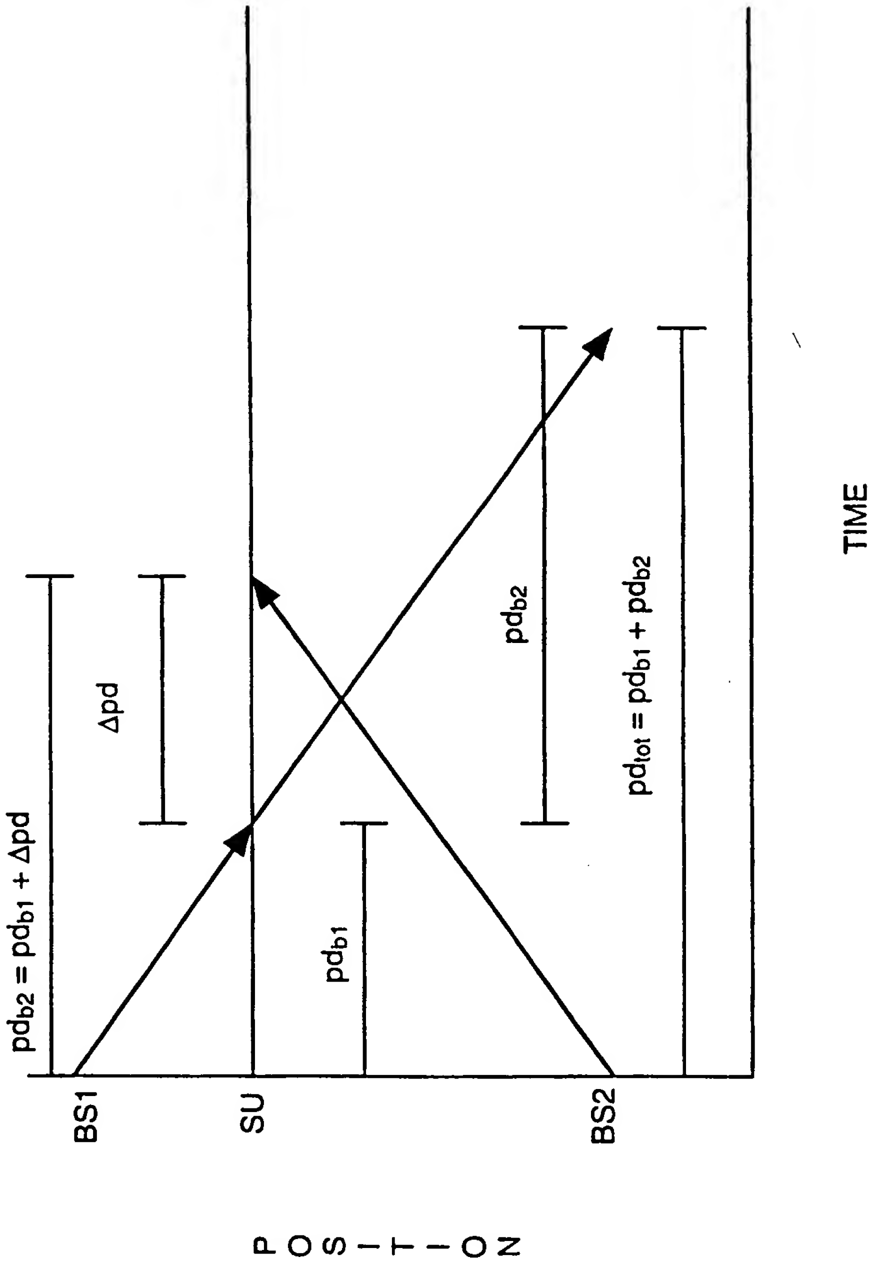
BS1
SU
BS2
POSITION
TIME
$pd_{b2} = pd_{b1} + \Delta pd$
Δpd
pd_{b1}
pd_{b2}
$pd_{tot} = pd_{b1} + pd_{b2}$

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US [illegible]08369

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 97 44984 A (QUALCOMM INC.) 27 November 1997 see page 21, line 2 - page 24, line 15; claim 1	1-16
P,X	WO 97 44970 A (QUALCOMM INC.) 27 November 1997 see claims 1,2	1-16
E	WO 98 27776 A (NORTHERN TELECOM LIMITED) 25 June 1998 see claims 1,2,5,7	1,3,16
P,X	WO 97 43837 A (MOTOROLA INC.) 20 November 1997 see page 8, line 30 - page 10, line 17	1,3,4,6, 8-16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 October 1998	09/10/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Leouffre, M

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INTERNATIONAL SEARCH REPORT

Int. tional Application No
PCT/US 8369

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	see page 3, line 24 - line 31	4,6, 9-11, 13-15
	see page 5, line 4 - line 14	

Y	WO 94 21057 A (TELEFONAKTIEBOLAGET LM ERICSSON) 15 September 1994	4,6, 9-11, 13-15
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X	WO 97 03531 A (TELEFONAKTIEBOLAGET LM ERICSSON) 31 January 1997 see page 10, line 17 - line 30 see page 11, line 27 - line 29 see page 12, line 35 - page 13, line 11; figures 1,3,6,7	1,3,6,8, 12,16

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Informatio[redacted]ent family members

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PCT/US [redacted]8369

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